QUANTUM FLUIDS

Hidden Duality and Associated Instabilities of Tomonaga-Luttinger Liquid on Lattice

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Hidden duality and associated instabilities of the spinless Luttinger liquid on a lattice are reported. The local quantum fluctuations and the long-distance chiral modes compete and as a result produce a hierarchy of exotic charge/density instabilities. Explicit bosonic quantum operators for the local density fluctuations are constructed and are used to make identification of the Luttinger liquid with the classical 2D Coulomb gas with theta-term and with the rich hidden duality.

Nuclear Spin Relaxation of Antimony in Liquid ^{3}He

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Measurements of the nuclear spin-lattice relaxation of powdered metallic Sb samples immersed in liquid ^{3}He have been carried out for the temperature range $1.25 < T < 150$ mK. The results show that the total nuclear spin-lattice relaxation rate is significantly enhanced with respect to the Korringa relaxation below 75 mK. This is attributed to the presence of a surface relaxation mechanism due to the modulation of the ^{3}He-Sb nuclear spin-spin coupling by the quantum zero-point motion of the ^{3}He atoms at the surface of the metallic particles. The strong coupling between the ^{3}He surface motions and the bulk ^{3}He phonons (including the coupling with the interlayer and bulk exchange motions) provides the final step in the link to the main thermal bath of the system. Similar processes have been reported for liquid ^{3}He in contact with insulators.[1-4]

This surface relaxation mechanism is very general and should be present for all materials containing unsaturated nuclear magnetic moments in contact with ^{3}He (solid or liquid). It is particularly important as a means of providing thermal contact in very low temperature applications and high magnetic fields where the spin polarizations are very high. These studies were carried out to obtain a detailed understanding of the mechanism for a metallic sample in liquid ^{3}He. The Korringa relaxation process for bulk metals and the surface relaxation mechanism have different temperature dependences. The former leads to a T_1 which is inversely proportional to temperature, while the latter is temperature independent. Because of this, the two relaxation processes can be separated by using a relaxation analysis used for studies of two-phase media or porous media. A detailed theory of the motionally induced surface relaxation mechanism has been carried out using a distribution of exchange rates at the surface based on the known variation on graphite surfaces. The theory is in good quantitative agreement with the experimental results.

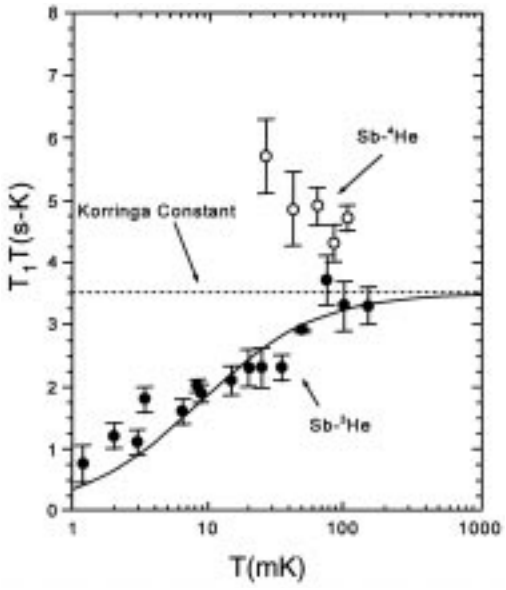

Figure 1. Observed temperature dependence of the nuclear spin-lattice relaxation of Sb particles in superfluid liquid helium three. The open symbols give the values for replacing liquid helium three with helium four.

References:

1 Sullivan, N.S., J. Low Temp. Phys., 22, 313 (1976).
2 Hammel, P.C., *et al*., Phys. Rev. Lett., 51, 2124 (1983).
3 Hammel, P.C., *et al*., Phys. Rev. B, 34, 6543 (1986).
4 Schuhl, A., *et al*., Phys. Rev. B, 36, 6811 (1987).

Orientational Ordering in Films of Molecular Films of Hydrogen on Boron Nitride

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Moderately high magnetic field (~ 7 T) high sensitivity NMR studies have been carried out to determine the orientational ordering of molecular hydrogen in films physisorbed on hexagonal boron nitride (BN). The NMR line shapes are directly related to the local quadrupolar order parameters, $\sigma = \langle 3J_z^2 - J^2 \rangle$, and

the phase changes can be observed very clearly from the changes in the NMR line shapes. The local orientational ordering of the molecular axes was in this manner determined for both thick films (12 layers) and thin films (bilayers).

The orientational ordering observed for ortho-H_2 molecules in thick films (12 layers) was very different from that seen for bulk H_2 and for commensurate monolayers on graphite. We have identified three distinct regimes for the ordering associated with clear changes in the detailed structure of the NMR lineshapes: (1) a high temperature rotationally disordered phase, (2) an intermediate temperature substrate crystal field (SCF) ordered phase limited to the first two to three layers near the substrate, and (3) at the lowest temperatures a mixed quadrupolar glass state and SCF ordered phase. The analysis of the substrate crystal field ordered spectra shows that the molecules close to the substrate behave as hindered rotors, leading to a large additional width in the spectrum from the spin-orbit coupling (I·J).

The bilayer films exhibit a completely different phase diagram to that observed for the thick films. The predominant features are the existence of a well defined long range orientational ordering for ortho fractions $X < 0.61$ with a region of coexistence of quadrupolar glass ordering and long range order for intermediate concentrations and temperatures. The transitions are sharp and the data is best understood if the orientational degrees of freedom of the two layers are tightly coupled together. Unlike the thick films we do not observe a large disordered component that persists to low temperatures. We attribute this to the influence of the substrate crystal fields that induce local orientational ordering in very thin films.

There is a sharp contrast between the orientational ordering observed for both bilayers and 12-layer films and that seen for bulk samples. The enhanced zero-point motion at the free surface apparently inhibits ordering for relatively thick films while the substrate interactions dominate the behavior for thin films. This behavior is a clear manifestation of the dependence of the ordering in frustrated systems on opposing geometrical constraints due to the presence of the substrate and the free surface. Understanding the different critical concentrations observed to be necessary for long range orientational ordering and glass ordering for the different geometries is a major challenge for the theory of these frustrated systems.

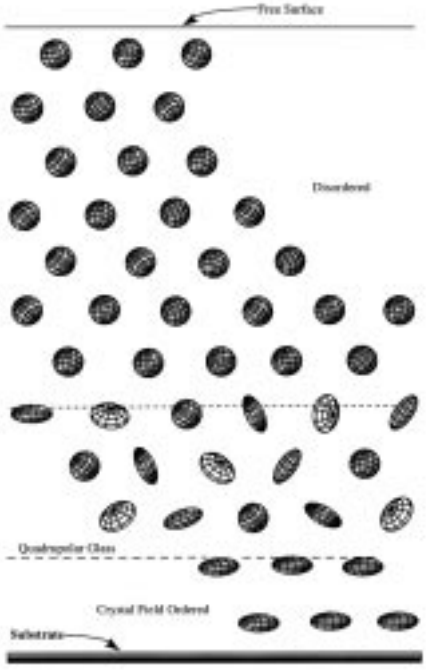

Figure 1. Schematic representations of the orientational ordering of quantum rotors (ortho-H_2 molecules) in thick films of H_2 on BN.

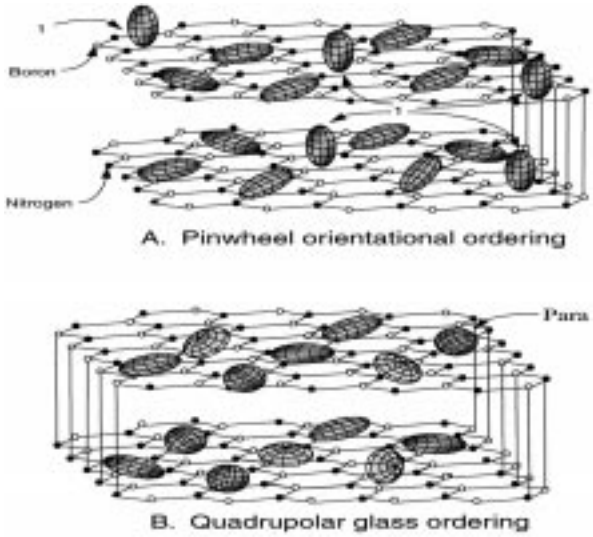

Figure 2. Schematic representation of the orientational ordering of quantum rotors (ortho-H_2 molecules) in bilayer films of H_2 on BN. The pinwheel ordering is inferred from the NMR studies for high ortho concentrations, and the quadrupolar glass state is seen at intermediate concentrations and low temperatures.